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The Effect of Social Distancing Measures on the Demand for Intensive Care: Evidence on COVID-19 in Scandinavia

Abstract

Understanding the effectiveness of social distancing on the spread of COVID-19 is crucial to justify economically costly social distancing measures. We present a case study focusing on the three Scandinavian countries. Whereas Denmark and Norway imposed relatively strict measures, Sweden follows an extraordinarily lenient approach. We use an event-study approach in which Sweden serves as a counterfactual to Denmark/Norway to estimate the measures' effectiveness. We estimate that in the counterfactual in which Denmark/Norway implemented Sweden's more lenient measures the number of hospitalizations would have peaked between around 15-20 days later. The peak number of hospitalizations in Denmark (Norway) would have been 133 (231) percent higher, and the peak number of ICU patients would have increased by 107 (140) percent.

JEL-Codes: I180, I120, H120.

Keywords: COVID-19, social distancing, intensive care, case study.

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"Closedown, lockdown, closing borders - nothing has a scientific basis, in my view. We have looked at a number of European Union countries to see whether they have published any analysis of the effects of these measures before they were started and we saw almost none."

Anders Tegnell, Swedish state epidemiologist[1,2]

I Introduction

Many countries have imposed social distancing measures in an attempt to halt the spread of COVID-19. The main rational behind these measures is that COVID-19, in the absence of social distancing, threatens to overwhelm the health care system. Hence, one of the objectives of the measures is to "flatten the curve", and spread the number of cases out over time. However, social distancing comes with severe economic costs (see for instance Adda, 2016, for an estimate). Most countries have already seen stark increases in unemployment and are predicted to have large losses in GDP. As exemplified by the quote of Tegnell above, relatively little is known about how effective the measures are in containing the spread of COVID-19, and hence, it is difficult to make a cost-benefit analysis.

We fill this crucial gap in our knowledge through a case study focusing on Denmark, Norway and Sweden. The three Scandinavian countries form an ideal laboratory for a case study. First, the three countries are similar in terms of health care institutions, culture, climate, and institutional framework.[3] Second, due to geographical proximity, and economic connections it is plausible that community spread of COVID-19 started at approximately the same time. In fact, Norway reported their 100th case on March 4, Sweden on March 6, and Denmark on March 9. Third, the social distancing regime varies strongly between the three countries. Whereas both Norway and Denmark introduced strong social distancing measures at approximately the same time, Sweden imposed relatively light restrictions. For instance, daycare centers and primary schools in Sweden remain open. Table 1 displays the dates of the introduction of various measures based on Hale et al. (2020). The difference in restrictions is reflected in mobility data. Google's COVID-19 Community Mobility Reports shows that the reduction in mobility is roughly twice as strong in Norway and Denmark as in Sweden (see Figure A.1 of the Ap-

[1]Source: 'Closing borders is ridiculous': the epidemiologist behind Sweden's controversial coronavirus strategy" Nature News Q& A retrieved from https://www.nature.com/articles/d41586-020-01098-x

[2]Sweden's constitution places the state epidemiologist in charge of initiating actions to contain the epidemic. Therefore, Tegnell plays a central role in Sweden's COVID-19 response.

[3]The three countries have close historical ties, their languages are mutually intelligible and despite their relatively small number of inhabitants, they are each in each others top 6 list of trading partners.

pendix). Fourth, hospitalizations and patients in ICU have peaked in Denmark and Norway, whereas Sweden appears to be very close to, or just over the top of the first peak (see Figure 1 below). Hence, by focusing on Scandinavia we can give a relatively complete picture of the first wave of COVID-19. We henceforth refer to March 12 as the 'lockdown' date, as it is the date on which most of the Norwegian restrictions came into place.

Table 1: Timing of the measures taken

Measure	**Denmark**	**Norway**	**Sweden**
S1 - School Closing	March 13 / 1	March 12 / 1	- / -
S2 - Workplace closing	March 13 / 1	March 12 / 0	- / -
S3 - Cancel public events	March 18 / 1	March 12 / 1	March 12 / 1
S4 - Close public transport	-/-	-/-	-/-
S5 - Record presence of public info campaigns	March 12 / 1	March 12 / 1	March 09 /1
S6 - Restrictions on internal movement	-/-	March 16 / 0	-/-
S7 - International travel controls	March 11	March 15	March 19

Note: The 0/1 after the date indicates whether a measure was general (1) or limited in scope (0).
For S3 & S4, we report the dates it was required; it may have been recommended before. For S7, we report the dates for bans, quarantine may have been mandated before. Source: Hale et al (2020).

The main variables of interest for our analysis are the number of COVID-19 hospitalizations and the number of patients with COVID-19 in intensive care. We focus on patients in hospitals and intensive care units (ICU) for two reasons. First, hospital beds, and specifically ICU beds are likely to serve as a bottleneck in the health care system, because relatively many patients with COVID-19 require hospitalization or intensive care, and supply in terms of personnel and equipment is limited in most countries. Therefore, if we are interested in the pressure on the health care system, these are the most important measures. Second, hospitalized patients, by definition, present with severe symptoms and are therefore likely to be tested in each of the three countries. Other measures, such as the number of confirmed infections, are likely to be affected by measurement error due to differences in the testing regime between the countries (see the next Section for a comparison across the three countries). For robustness, we also consider the effect of the lockdown on cumulative deaths.

Our methodology is an event study. Sweden serves as our control group, whereas Denmark and Norway each function as a treatment group. We divide our data into 5-day periods, and estimate coefficients for each of the 5-day periods through the difference-in-difference between Denmark/Norway and Sweden.

We face a number of methodological issues. First, before March 18 there exists no comparable data on hospitalizations and ICU patients between the three countries.[4] Second, the lockdown is unlikely to immediately affect hospitalizations, since there is a significant gap between infection and potential hospitalizations (and an even larger gap for potential secondary infection).

We solve these issues by treating the first 10 days of our data, March 18-March 27 (6-15 days into lockdown), as our 'before'-period. In this period, we do not expect that the lockdown measures have a significant impact on hospitalizations and ICU patients, and hence, cases in Denmark, Norway and Sweden should follow a common trend.

Our analysis shows that this is indeed the case. Both our raw data (Figure 1), and the coefficients in our event study analysis show that the three countries have similar COVID-19 hospitalizations up to around 15-20 days into lockdown. After that hospitalizations and ICU patients begin to diverge rapidly, increasing in Sweden, and plateauing in Denmark/Norway.

We use our event study model to predict the peak number of patients Denmark and Norway would have had in the absence of lockdown. Our model predicts that the peak in hospitalizations would have occurred between 15-20 days later. For Denmark (Norway) there would have been 133 (231) percent more hospitalizations at the peak. For patients in ICU the peak would have been 107 (140) percent higher.

We also estimate our model on the cumulative number of deaths. We find that with respect to deaths, Denmark and Sweden initially had very similar experiences. However, in Norway we find evidence of pre-trends indicating that deaths in Norway, relative to Sweden, started reducing very early in the lockdown period.[5] We believe these pre-trends cannot plausibly be tied to the lockdown measures, and therefore refrain from interpreting Norway's results on deaths causally. Our model predicts that Denmark, at the end of the sample period, would have had 167 percent more cumulative deaths, had they decided not to initiate lockdown.

Related Literature A number of recent studies consider the impact of social distancing measures on the spread of COVID-19. Most prominently, Ferguson et al. (2020) estimate the effect of social distancing measures on COVID-19 using cross-country data. Their empirical approach is to compare the prediction of epidemiological modeling estimated on data prior to intervention to actual outcomes. The main variable they focus on is deaths as it is the only variable comparable across a large set of countries.

[4]Specifically, initially Sweden reports the number of patients that are, *or have been* hospitalized. Denmark reports only patients that are currently hospitalized. Norway reports both. From March 18 onwards all countries report the number of patients that are hospitalized.

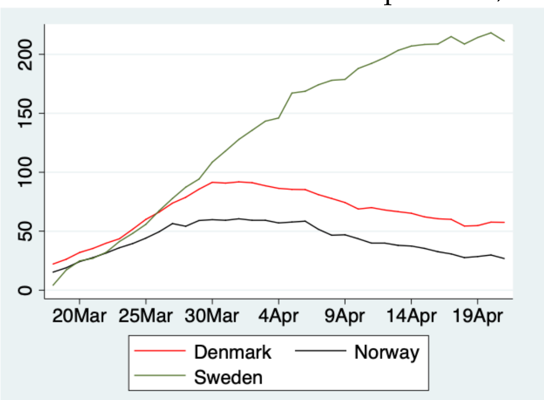
[5]We confirm this finding using data on deaths prior to March 18, which is available for all three countries.

Their approach leverages the statistical power that comes with pooling data from many countries. However, a relative disadvantage is that identification relies strongly on structural assumptions regarding the epidemiological model, which may not provide a good fit for every single country. In contrast, in our case study the effect of social distancing is readily visible in raw data (see for instance Figure 1), and hence identification does not rely as much on functional-form assumptions.

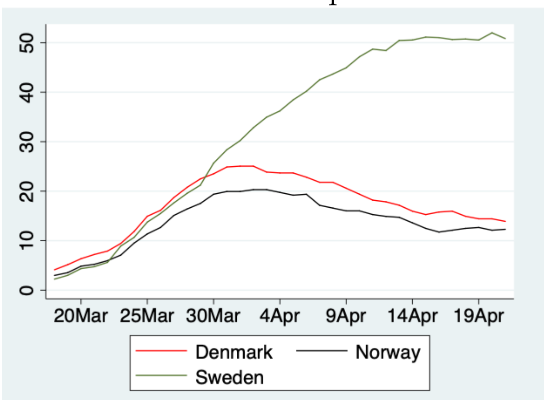
Chinazzi et al. (2020), Fang et al. (2020) study the effect of travel restrictions on the spread of COVID-19 in China. Although, the Scandinavian countries have also introduced some travel restrictions in the wake of COVID-19, we believe that the main effect in our paper is instead driven by social-distancing measures, since the Scandinavian travel restrictions were only enacted after community spread had occurred.

II Data

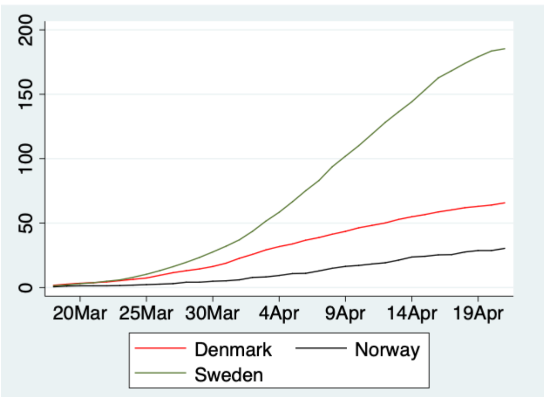
Figure 1: Number of Patients hospitalized, in ICU and cumulative deaths per 1 mn inhabitants



a. Hospitalizations



b. Intensive Care Patients



c. Cumulative Deaths

The dependent variables in our analysis are: the number of patients in ICU for COVID-19, the number of patients in the hospital for COVID-19 and the cumulative number of deaths related to COVID-19 each per 1 million inhabitants. For Norway and Denmark we collect all data from the national health authorities. One caveat is that Norway does not report patients in ICU until March 23. Therefore, in the period March 18-March 23 we use patients on a respirator as a proxy for ICU patients in Norway.

For Sweden, the national health authority only publishes daily data on current hospitalizations, and on current ICU patients from March 30 onwards. Therefore, we complement the data with data from the Swedish aggregation website C19.se. C19.se collects data from the Swedish Public Health Agency, the intensive care register, regional authorities, and the Swedish national television broadcaster (SVT). They only report data that has been confirmed by at least two sources. We confirm that after March 30, the data on c19.se coincides with the data published by the Swedish Public Health Agency.

Figure 1 shows our dependent variables. The variables initially follow a similar pattern in all three countries until somewhere between March 25 and March 30 (13-18 days into lockdown). After that Sweden continues reporting more hospitalizations and patients in ICU, whereas the numbers in Denmark/Norway begin to plateau, and decrease in the more recent weeks. In Sweden numbers begin to stabilize two weeks later but at a much higher level.

By definition, the cumulative number of COVID-19 deaths continues to increase in all three countries, albeit at a much steeper rate in Sweden.

In our analysis Sweden serves as a counterfactual to Denmark and Norway, because it is the only country that has not initiated strict lockdown measures. It is therefore crucial to understand the similarities and differences between Sweden and the other two countries. Table 2 displays some key characteristics of Denmark, Norway and Sweden collected from the national statistics offices, Eurostat and Rhodes et al. (2012)

Sweden has roughly twice the population of Denmark and Norway. In our analysis, to account for this difference, we consider only per capita measures of hospitalizations/ICU patients. In contrast, Denmark has a significantly higher population density. This is relevant, because in the absence of lockdown measures epidemics are likely to spread faster in countries with higher population density. Therefore, in the case of Denmark, using Sweden as a counterfactual may underestimate the effectiveness of the lockdown measures. Norway has a lower population density than Sweden, and results may therefore be biased in the opposite direction.

All three countries spend roughly the same percentage of their GDP on health care. How-

Table 2: Key country characteristics

	Denmark	Norway	Sweden
Population	5 827 463	5 367 580	10 327 589
Population density (per km^2)	135.7	13.9	22.9
GDP per capita (in PPS)	126	150	121
Health care spending (% of GDP)	10.2	10.5	11.0
Life expectancy at birth (years)	81.1	82.7	82.5
Hospital beds (per 1mn inhabitants)	2 608	3 600	2 036
ICU beds (per 1mn inhabitants)	67	80	58
Date first 100 cases	March 09	March 04	March 06
Cases until April 21	7 863	7 250	15 804
Cases until April 21 (per 1mn inhabitants)	1 349	1 351	1 530
Tests until April 21	106 623	145 279	93 701
Tests until April 21 (per 1mn inhabitants)	18 297	27 066	9 073

Sources: Population data 2020: National Statistics Offices. GDP 2018, Health care spending 2016, Life expectancy 2017, and Hospital beds 2017: Eurostat. Intensive care beds 2011 includes intensive care and intermediate care beds: (Rhodes et al., 2012).
Cases, tests and cumulative deaths: Danish Health Authority (Sundhedsstyrelsen), Norwegian Institute of Public Health (Folkehelseinstitutt), Swedish Public Health Agency (Folkhälsomyndigheten) and C19.se.
Note: PPS: Eurostat's Power Purchasing Standard in relation to the European Union average set to equal 100.

ever, we do observe differences in terms of the hospital capacity. Norway has the highest number of hospital beds in general and ICU beds in particular. In this respect it is somewhat surprising that Sweden, having the lowest hospital capacity, did not lock down the economy. Only the stabilization of the curve in Sweden in the last week of our sample protected Sweden from reaching their capacity limit.[6]

Furthermore, we obtain data on the development of the ongoing COVID-19 pandemic from the national health authorities. The second panel of Table 2 shows the number of positively tested persons, and the number of tests performed as of April 21.

Sweden has the highest number of confirmed cases per 1mn inhabitants, but the difference with Norway and Denmark is very small. However, these numbers are difficult to compare because the countries implemented different testing policies. Norway has performed around three times as many tests, and Denmark twice as many tests as Sweden per capita. This clearly shows that it is not possible to compare the number of cases across the three countries.

III Results

To quantify the effect of the lockdown we estimate an event study model. We do not have enough degrees of freedom to estimate a dummy for each day and each country. Therefore, in-

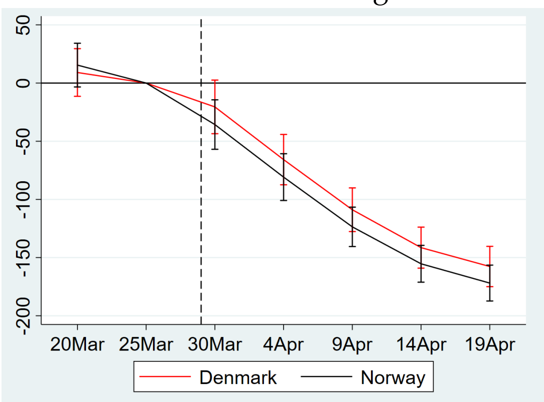
[6]Note that the numbers on hospital capacity should be interpreted with care, as it is likely all three countries increased capacity in the wake of the COVID-19 pandemic.

stead we divide our days into 5-day periods starting from March 18, the start of our dataset. For each 5-day period we calculate the difference-in-difference (DiD) between Denmark/Norway and Sweden for our outcome variables using the second 5-day period March 23-28 as our baseline. The regression equation is given by:

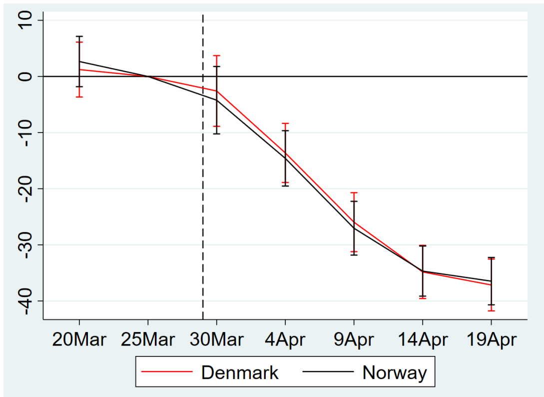
$$y_{ct\tau} = \beta_{c\tau} + \alpha_c + \gamma_\tau + \epsilon_{ct\tau}, \tag{1}$$

where $y_{ct\tau}$ denotes the outcome variable in country c, day t and 5-day period τ. For our outcome variables we use the number of patients in ICU, the number of hospitalizations and cumulative deaths each per 1 million inhabitants. α_c are country-fixed effects and γ_τ denote 5-day-period-fixed effects. Our coefficient of interest is $\beta_{c\tau}$ measures the DiD in $y_{c\tau t}$ between Denmark/Norway and Sweden in the 5-day period τ, using $\tau = 2$ as the baseline.

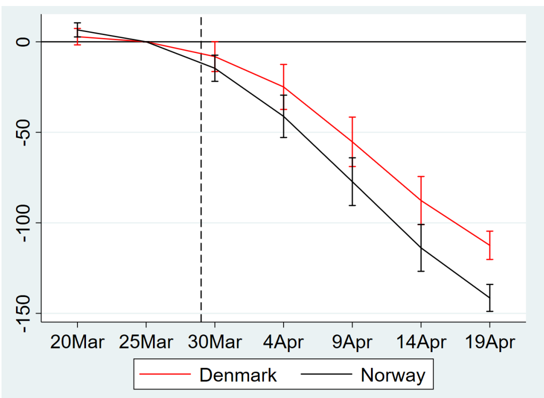
Figure 2: The effects of lockdown



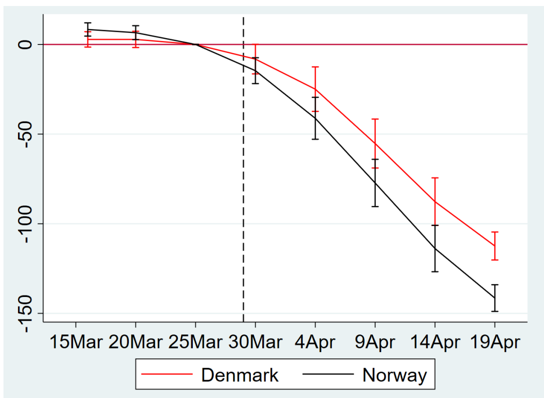
a. Hospitalizations



b. Intensive Care Patients



c. Cumulative Deaths



d. Cumulative Deaths

Notes: The figure shows results from regression equation (1) for the outcome variable shown in the caption. The coefficient for each 5-day period is shown on the third day of the period together with a 95-percent confidence interval, which we calculate using robust standard errors. The coefficient for the 5-day period (March 23-27) is normalized to 0. The sample for panel a-c runs from March 18-April 21. For panel d the sample runs from March 13-April 21. The underlying regression results are reported in Table A.1.

Results are presented in Figure 2 and Table A.1. Panels a and b show that initially hospitalizations, and patients in ICU follow a similar trend in Denmark, Norway and Sweden. However, at the end of March, hospitalizations and patients in ICU start reducing markedly in Denmark and Norway, relative to Sweden. The trend in Denmark and Norway remains remarkably similar. In the final period the effect of the lockdown begins to level out which is consistent with the curve for hospitalizations and ICU patients flattening in Sweden (see Figure 1).

Panels c and d each consider the effect on deaths. For Denmark early coefficients are close to zero and non-significant, indicating that deaths initially follow a common trend in Denmark and Sweden. For Norway, the early coefficients are significant and positive. This provides some evidence that deaths in Norway and Sweden were on different trends very early after lockdown. It is implausible that this difference in trends is driven by the lockdown measures, since the coefficient in panel d is already significant in the period March 13-March 17, only 1-5 days into lockdown. Therefore, we do not interpret the Norwegian results for cumulative deaths causally. For Denmark, from the beginning of April onwards, deaths begin to reduce rapidly, relative to Sweden.

To better understand the impact of lockdown on hospital and ICU capacity, we use our model to make predictions on the peak number of COVID-19 patients in Danish and Norwegian hospitals in the counterfactual in which they would have followed Sweden's more lenient social distancing approach. Our approach is as follows. First, we use the raw data to find the maximum number of patients in hospitals/ICUs in Denmark and Norway, and the date on which the peak occurs. Second, we find the counterfactual number of patients by predicting the number of patients in the absence of treatment (i.e. removing the treatment effect $\beta_{c\tau}$. Mathematically, the model-predicted counterfactual outcome variable is given by:

$$y^{cf}_{ct\tau} = \hat{\alpha}_c + \hat{\gamma}_\tau,$$

where hats denote estimated values.

Results are reported in Table 3. Our model predicts that in the counterfactual without lockdown, Denmark would have seen 107 percent more patients in ICU at the peak, and 134 percent more overall hospitalizations. The peak would have occurred between around 15-20 days later. At the end of our sample, cumulative deaths would have been 167 percent higher.

Table 3: Peak analysis

a. Denmark	(1) Peak Date	(2) Counterfactual Peak Date	(3) Peak Size	(4) Counterfactual Peak Size	(5) Relative difference
Hospitalizations	Apr 01	Apr 17-21	91.81	214.53	133.68 %
ICU	Apr 02	Apr 17-21	25.05	51.87	107.05 %
Cumulative Deaths	NA	NA	65.72	175.39	166.87 %
b. Norway					
Hospitalizations	Apr 01	Apr 17-21	60.55	200.59	231.29 %
ICU	Apr 03	Apr 17-21	20.31	48.81	140.34 %
Cumulative Deaths	NA	NA	30.37	169.63	458.60 %

Notes: The table presents results for the actual peak and the model-predicted counterfactual peak in hospitalizations, number of patients in ICU, and cumulative deaths each per 1 million inhabitants. Column 1 presents the actual date in which the variable described in each row peaks. Column 2 contains the model-predicted counterfactual peak date. Note that coefficients only change every 5 days, and thus the peak date is a 5-day range. Column 3, and 4 provide the size of the actual, and the counterfactual peak. Column 6 contains the increase in the counterfactual peak relative to the actual peak. Note that cumulative deaths, by definition, do not peak. Instead, here we provide the size of the actual and counterfactual number at the end of our sample on April 21.

For Norway effects are even larger with a 140 percent increase in ICU patients and a 231 percent increase in overall patients. The peak would have occurred between around 15-20 days later. The model also predicts a 466 percent increase in deaths, but as discussed above we refrain from interpreting this number causally due to the presence of pre-trends.

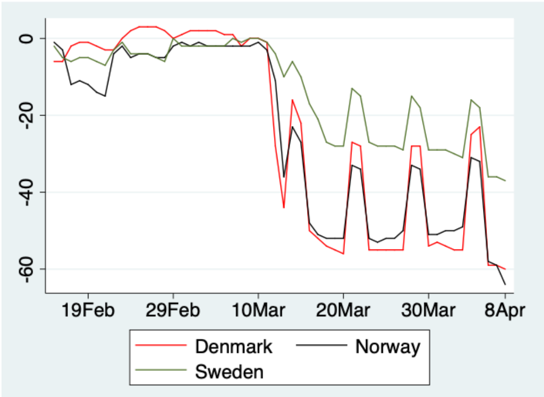
IV Conclusion

Our case study compares the effect on the health care system of the strict lockdown measures by Denmark and Norway with the more lenient approach of Sweden. We show that the stricter measures decrease the stress on the health care system.

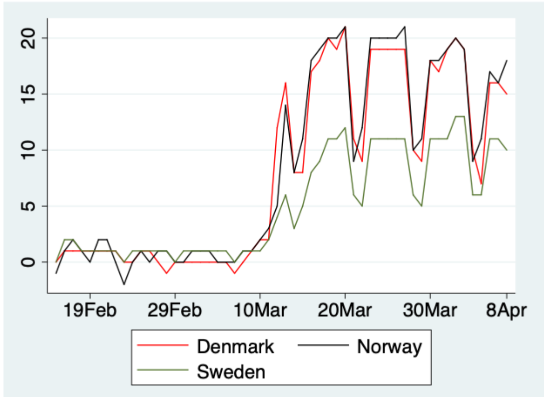
Compared to the more lenient approach of Sweden, the lockdown measures strongly reduce the number of hospitalizations and intensive care patients per capita. Our counterfactual analysis reveals that following the Swedish approach would have resulted in more than twice as many hospitalizations and intensive care patients at the peak, potentially bringing Denmark and Norway close to their maximum capacity. These results are important for the discussion of the lockdown measures, because they help to quantify the benefits of the economically costly measures.

A Appendix Materials

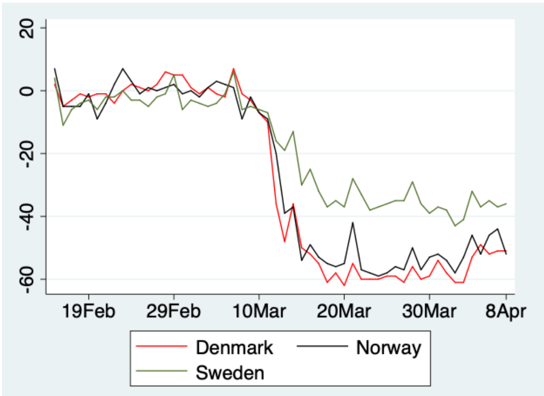
Figure A.1: Activity in Denmark, Norway and Sweden compared to the baseline



a. Work places



b. Residential areas



c. Transit stations

Note: The figures show how visits and length of stay at different places change compared to the median value, for the corresponding day of the week, during the 5 week period Jan 3 -Feb 6, 2020. The figure a and b contain some spikes. These are caused by weekends. On a normal weekend, most of the workforce is off-duty. Therefore, on those days the changes to the baseline are less pronounced. Note that the spike in February in Norway in figure a is presumably caused by the winter holiday in large parts of the country.
Source: Google LLC "Google COVID-19 Community Mobility Reports." `https://www.google.com/covid19/mobility/`, Accessed: April 22, 2020

Table A.1: Event Study

	(a) Hospitalizations	(b) ICU	(c) Cumulative Deaths	(d) Cumulative Deaths
DK 13.03-17.03				2.807
				(2.141)
DK 18.03-22.03	9.075	1.230	2.815	2.815
	(10.233)	(2.445)	(2.264)	(2.264)
DK 28.03-01.04	-20.488*	-2.587	-8.175*	-8.175*
	(11.525)	(3.150)	(4.120)	(4.120)
DK 02.04-06.04	-65.779***	-13.629***	-24.935***	-24.935***
	(10.812)	(2.633)	(6.207)	(6.207)
DK 07.04-11.04	-108.865***	-25.965***	-55.263***	-55.263***
	(9.381)	(2.629)	(6.824)	(6.824)
DK 12.04-16.04	-141.446***	-34.831***	-87.679***	-87.679***
	(8.818)	(2.368)	(6.635)	(6.635)
DK 17.04-21.04	-157.664***	-37.151***	-112.415***	-112.415***
	(8.658)	(2.309)	(3.903)	(3.903)
NO 13.03-17.03				8.361***
				(1.845)
NO 18.03-22.03	15.435	2.663	6.570***	6.570***
	(9.395)	(2.243)	(1.945)	(1.945)
NO 28.03-01.04	-35.660***	-4.227	-14.627***	-14.627***
	(10.625)	(3.003)	(3.609)	(3.609)
NO 02.04-06.04	-80.831***	-14.594***	-41.184***	-41.184***
	(10.044)	(2.465)	(5.851)	(5.851)
NO 07.04-11.04	-123.576***	-27.041***	-77.247***	-77.247***
	(8.460)	(2.395)	(6.591)	(6.591)
NO 12.04-16.04	-155.327***	-34.680***	-113.826***	-113.826***
	(7.903)	(2.232)	(6.472)	(6.472)
NO 17.04-21.04	-171.899***	-36.474***	-141.463***	-141.463***
	(7.708)	(2.107)	(3.721)	(3.721)
13.03-17.03				-10.186***
				(1.824)
18.03-22.03	-37.046***	-9.295***	-7.688***	-7.688***
	(8.161)	(1.695)	(1.921)	(1.921)
28.03-01.04	49.111***	11.716***	17.235***	17.235***
	(9.920)	(2.578)	(3.582)	(3.582)
02.04-06.04	94.059***	23.239***	48.375***	48.375***
	(9.353)	(2.041)	(5.809)	(5.809)
07.04-11.04	124.172***	32.108***	90.922***	90.922***
	(7.386)	(1.944)	(6.518)	(6.518)
12.04-16.04	146.869***	37.027***	134.320***	134.320***
	(6.905)	(1.656)	(6.371)	(6.371)
17.04-21.04	155.467***	37.666***	167.396***	167.396***
	(6.759)	(1.603)	(3.625)	(3.625)
N	105	105	105	120
r2	0.985	0.981	0.987	0.988

Notes: This is the regression table that was used to generate Figure 2. The dependent variable in column a reports the number of hospitalizations per 1 million inhabitants. In column b the dependent variable is the number of ICU patients per 1 million inhabitants. Cumulative deaths per 1 million inhabitants is the dependent variable in column c and d. The independent variables are dummies for the dates listed in the rows interacted with country dummies. For instance, "DK 18.03-22.03" denotes a dummy that equals 1 from March 18 to March 22 for Denmark. All regressions include country-fixed effects. Robust standard errors reported in parenthesis. Asterisks denote: $***p < 0.01, **p < 0.05, *p < 0.1$.

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